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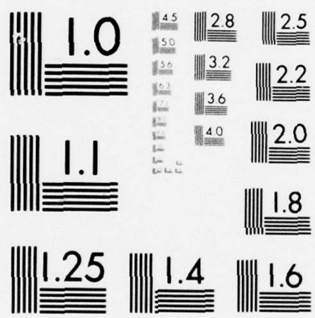

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

RESEARCH DEPARTMENT

ASW LABORATORY BROCHURE

May 1966

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INTRODUCTION

This brochure describes the Grumman Research Department ASW Laboratory and other Research facilities that are available for ASW research. The ASW Laboratory is being used for simultaneous studies in the following areas: 1) underwater phenomena, including acoustics and electromagnetics, 2) infrared phenomena, and 3) optical signal processing. Supporting facilities are used for additional signal analysis, analog and digital computing, A-D and D-A conversion, and other associated tasks. A description of the laboratory and facilities is given ~~in the following sections~~ along with examples of typical research programs. Additional information concerning the ASW Laboratory and research programs may be obtained by contacting the Grumman Aircraft Engineering Corporation, Research Department, Plant 25, Bethpage, New York 11714.

HYDROACOUSTIC FACILITY

The hydroacoustic facility in the ASW Laboratory was established early in 1960. In subsequent years, the facility has grown in physical size and instrumentation complexity. Photographs of the facility are shown in Figs. 1 and 2. The tank and most of the electronic equipment were purchased commercially, but practically all of the electromechanical systems were designed by the Research personnel for specific needs. Some of the more pertinent equipment is described below.

Tank

The tank is 15 feet in diameter and 10 feet deep; it is of conventional construction with 3-inch thick porous white cedar staves and floor. The hoops are made of austenitic stainless steel and are electrically insulated with a heat shrinkable PVC sleeving. The lugs joining the hoop sections together are made of high strength aluminum and are insulated by an epoxy coating. The tank is set upon special dunnage, made of wood, cork, and rubber, that is designed to minimize the transmission of building vibrations into the water. The tank and its associated structure offer a quiet, nonmagnetic environment for experiments.

The tank holds ordinary tap water at room temperature and is kept clean by nighttime filtration. The entire volume of water can be cleaned by filters of 10 micron mesh in 10 hours. The pH and chlorine content of the water are checked daily so that the entire volume of water remains crystal clear at all times.

Mechanical Handling Equipment

A two rail, multiple carriage system (Fig. 1) to suspend and position equipment is mounted on the top of the tank. The rails are aluminum "I beams" on top of which are simple inverted vee guides for the carriages that can be positioned anywhere desired. Closed-loop electric servos on the carriages rotate or elevate the equipment suspended in the water. Equipment can be positioned

also in the tank by a pair of independent submerged "swings" whose pivot points are located near the top edge of the tank. Figure 3a shows schematically that a receiver and transmitter on the individual swings are directed toward the same water surface area, regardless of the angular position. Closed-loop hydraulic servos control the position of the swings, thus allowing the operator to dial in the angular positions from the operating console shown in Fig. 2. Recordings, such as that shown in Fig. 4a of the acoustic energy scattered by the water surface, can be made when one swing is synchronized with a polar chart recorder.

Figure 3b shows another pair of swings that are designed to direct a pair of hydrophones at a certain volume of water. These "vertical swings" have one pivot point at the bottom of the tank and the other just above the water surface. The upper pivot point and hydraulic drive can be seen in Fig. 1 on the center of the rails. This pair of swings automatically positions the hydrophones so that they are continuously directed toward the same volume of water during the entire 360 degrees of rotation. Recordings (such as that shown in Fig. 4b) of the energy scattered by a rising slab of bubbles can be made when one swing is synchronized with a polar chart recorder.

Wave Generator

A surface piercing wedge, Fig. 5, (shown schematically in Fig. 3a) is moved up and down to produce a wave train that propagates across the surface of the tank. The surface wavelengths are controlled by the frequency of the wedge motion and wave heights by the amplitude of the wedge motion. Reflections of the wave train at the tank walls are minimized effectively by wave absorbers placed along the tank walls. Wave facets, which attenuate quite rapidly, are produced by an air stream directed onto the water surface. Any sea condition from ordinary sine wave swells to a fully developed sea can be simulated. Typical spectra for two fully developed sea simulations are shown in Fig. 6. The dashed lines denote the simulated ocean conditions.

Underwater Sound Sources

Several types of sound sources are available for acoustic experiments. One type, an underwater spark discharge (3000 joules at 25 kv), is used to simulate underwater explosions. The power supply, from Dell Electronics, was repackaged by us with triggering

circuits. The sound source portion of this equipment and a typical acoustic pulse for a 200 joule excitation are shown in Fig. 7. The pulse has a time constant of about 20 μsec, which is quite repeatable and has more intensity than really required in a 15-foot tank.

Commercial hydrophones (Fig. 8) are used to simulate sonar pulses. The acoustic output shown is the shortest pulse that can be obtained from such a hydrophone at 100 kc due to its transient response. The source is extremely repeatable, as can be seen from the acoustic output in Fig. 8, which shows 40 successive pulses. Pulses of frequency chirps, random noise, and pseudo-random noise may also be transmitted with this hydrophone. The acoustic output of the hydrophone can be made directional by placing the hydrophone in a reflector shaped to produce the desired beam pattern. Our reflectors are specially constructed so as to prevent distortions in the beam pattern caused by internal reflections in the reflectors.

We have constructed an eddy current, sound source device (Fig. 9) that produces a much shorter pulse than can be obtained from commercially available equipment. When a capacitor — storage power supply is discharged into the wire spiral, eddy currents are induced in the aluminum disk. The resulting magnetic fields repel the disk and produce an acoustic pulse containing only one cycle of an 80 kc sine wave as shown in Fig. 9. The end cap and rubber washer provide a flexible mount for the thin disk, and the conical shape at the right end minimizes interfering internal reflections.

Electronic Systems

The equipment used in a typical experiment in underwater acoustics is shown in the block diagram of Fig. 10. The first row of equipment is used to generate sonar pulses; the second row is timing circuits, while the third row is receiving equipment and some readout components frequently used. The transmitting and receiving equipment can be operated between 25 and 400 kc/sec; the dynamic range is in excess of 75 db at 200 kc/sec, however, many of the components have a much larger bandwidth. Notice that commercial mercury-wetted relays are used in the receiving system for gating. They have been found highly satisfactory in providing a gate as narrow as 1.9 msec, are energized by commercial pulse generators, and have negligible cross-talk or feed-through. As shown in the transmitting system, we also use Tektronix plug-in equipment for some gating functions.

Acoustic Test Environment

Background noise, which is largely below 200 cps, has been almost entirely eliminated by electrical and mechanical filtering; this makes the tank a quiet environment for acoustic experiments. The reverberation-free listening time is 2 msec. Various baffles, absorbers, and directional acoustic sources are available for increasing this time for some experiments.

The speed of sound in the tank must be accurately known, because many analyses are based on path length and time considerations. The speed is determined by measuring the time it takes for acoustic pulses to travel between two hydrophones, and then plotting this time against the change in hydrophone spacing. The slope of a linear least squares line fitted to the data is the speed. This method has two advantages: 1) only the change in hydrophone spacing need be known, and 2) all time lags are the same for each measurement. The possible error in hydrophone position increment varies from 1 part in 1000 to 1 part in 2500. The maximum error in travel time, measured by a 10^7 cps counter, is 1 part in 2000.

INFRARED WAKE DETECTION FACILITY

This facility is designed primarily to study the infrared characteristics of the surface wakes generated by submerged submarine models. The basic elements of the laboratory facility, shown in Figs. 11 and 12, are an infrared scanning system, test tank, thermistor probe arrays, and submarine models.

Scanner

The infrared scanner consists of a radiometer with Cassegrainian type optics. Scanning action is provided by oscillating a mirror which sweeps the radiometer's field of view across the width of the tank. The mirror and radiometer are mounted on a carriage as a unit that can be translated down the length of the tank. Thus one can make a two dimensional map of the temperature distribution of the water surface. The oscillating mirror has a frequency range of 0 to 5 cps, and the carriage containing the radiometer and mirror combination has a velocity range from 0.2 in./sec to 15 in./sec. The radiometer optics have been aspherized for minimum blur circle (0.074" dia) at a distance of 40 inches. This permits spot size variations from 0.074 to 8 inches, neglecting obscuration from the secondary mirror. The radiometer detector is an uncooled, germanium immersed, thermistor bolometer with a spectral response of 1.8 to 20 microns. The radiometer has noise equivalent temperature (NET) of approximately 0.02°C measured in a 1 cps bandwidth at 25°C.

Tank

The test tank is 6 x 3 x 2 feet with glass sides that permit a visual study of the submerged flows generated by the models. In addition, the tank lends itself to visualization of such natural phenomenon as convection cells, some typical examples of which are shown in Fig. 13. These cells were outlined by using a water soluble dye that fluoresces in the visible part of the spectrum when stimulated by ultraviolet radiation. The UV light sources are mounted just underneath the scanner support structure shown in Fig. 12. Rapid filtration is accomplished by a water circulating system located within the tank support structure shown in Fig. 11.

Thermistor Probes

Various thermistor probe arrays have been constructed at Grumman, one of which is shown in the center of Fig. 12 near the submarine model. These probes consist of Veeco 51A32 thermistor beads inserted in hypodermic tubing 0.03 inch in diameter. The small size of these probes permit a high density packing at discrete points, with minimum effect on water flow. When the probes are used in ordinary wheatstone bridges, sensitivities of 0.01°C can be achieved in the temperature range of 20 to 40°C.

Both horizontal and vertical probe arrays are used to provide a two dimensional time history of the thermal structure within the volume. In addition, the vertical probe array can be precisely positioned across the air-water interface to monitor boundary temperatures.

Submarine Models

Several different scaled models are available. These include both self-propelled and towed models. The self-propelled model contains an electric motor whose power supply is external to the tank. The guide lines are used to provide power to the motor, thereby eliminating any extraneous water flow caused by trailing lines. These lines are fastened at both ends of the tank to a "universal" type of supporting system that enables both the self-propelled and towed models to be positioned anywhere within the tank. The forward velocity of the models is accurately controlled by a velocity servo drive with a speed range of 0.4 to 20 in. sec.

Electronic Systems

The block diagram of Fig. 14 shows some of the equipment used in this facility. The mapping system employs a hydraulic actuator to drive the scanning mirror. The function generator, which acts as the input to this closed-loop servo, enables the mirror to be driven by a variety of periodic signals. The displacement transducer mechanically connected to the mirror shaft provides a feedback signal proportional to mirror position, which in addition to closing the loop, is fed to the Y input of an X-Y recorder. A velocity servo drives the carriage containing both the radiometer and mirror. A displacement transducer fixed to the carriage provides a signal proportional to carriage position. This signal,

together with the filtered output of the radiometer, is summed in an operational amplifier and then fed to the X input of the X-Y recorder. The system arranged in this fashion permits the display of three parameters in a two dimensional format. A typical example of this type of recording is shown in Fig. 15.

In conjunction with the above system, a three dimensional (facsimile) recorder has been ordered and will be used in addition to the X-Y recorder. This instrument records the radiometric signal as a density variation on the recorder paper versus mirror and carriage position, which are the two dimensions of the recorder paper. The recorder uses dry electrosensitive paper and has a dynamic range of 26 db.

Also shown on the block diagram in Fig. 14 are the data processing methods presently in use. The radiometer output is filtered and then recorded on magnetic tape for future analysis using the equipment described in the Signal Analysis and Computing Sections of this brochure.

The thermal probe equipment shown in Fig. 12 is used to measure the thermal structure within the water. The probes in the array can be sampled sequentially at a rate of from 0.1 to 10 seconds per probe, or their output can be recorded continuously on multichannel recorders. An example of the thermal structure recorded continuously by a vertical probe array is shown in Fig. 16.

Spectrophotometer Equipment

Our examination of the infrared characteristics of a water surface has led to a study of the optical transmission properties of sea water that have been modified by various phenomena produced by a submarine. The basic elements of this part of our facility are a dry box and a Beckman DU Spectrophotometer. The interior of the dry box is constantly purged with dry helium which permits the preparation of the samples in a dust free environment. The spectrophotometer is used to measure the absorbence, transmittance, and energy spectra with a spectral range of 0.16 to 3.5 microns. The results of this program to date are classified.

SIGNAL ANALYSIS FACILITY

The Research Department has a comprehensive amount of equipment for the recording and analysis of experimental data. In addition to the equipment already described, the signal analysis equipment allows a rather extensive signal processing of the data to be made. A photograph of some of the equipment is shown in Fig. 17.

Data can be analyzed spectrally with a Technical Products Company 625 analyzer. This instrument can be used to analyze periodic, aperiodic, and random functions, and can produce the Fourier series, Fourier integral, power spectral density, and probability density of the data. Its frequency response is 2 cps to 25 kc/sec, but this range can be greatly extended by speed changes available in the magnetic tape recorders. A typical example of a power spectrum of data analyzed using this equipment is shown in Fig. 18.

Several instrumentation magnetic tape recorders are available for either FM or analog recording of laboratory data. Up to seven channels of 100 kc/sec data may be recorded simultaneously on each recorder and analyzed at a later date. Loop adapters are frequently utilized on the recorders as well as searcher-coder equipment.

The option of processing data digitally is available through a data link between the ASW Laboratory and the computing facility (described later). The computing facility can calculate the same functions (and others) as the spectrum analyzer, but much faster. In addition, it extends the frequency range of analysis down to dc. An example of a spectrum obtained digitally is shown in Fig. 19.

In addition to a host of general purpose electronic laboratory equipment, the signal analysis facility is equipped with the following peripheral equipment:

Spectrum analyzer (Kay Electric "Sonograph," modified)

Signal storage and time delay device for autocorrelation and cross-correlation of data (Kay Electric "Autovox," modified and augmented)

Amplitude probability distribution analyzer (Automation Laboratories Model 200)

Portable analog computers for signal conditioning and analysis (Donner Model 3500).

COMPUTING FACILITY

The computing facility available for Grumman ASW research is extensive. The digital facility is comprised of two IBM System 360/30, two IBM 7094-II, two IBM 1620 and three IBM 1460 Electronic Data Processing Systems, with an IBM 360/75 due in June. The analog facility contains more than 1400 amplifiers with a large complement of function generators, servomultipliers, and electronic multipliers; and a McCann Direct Analog computer. These machines permit the solution of scientific problems and the processing of experimental information of very large scope and complexity. However, despite the capacity of the individual analog and digital facilities, there remain certain research problems for which detailed solution by either an all-analog or an all-digital computer is awkward. To handle these cases, the digital and analog equipments may be interconnected with our ADAGE 770 Computer Link providing 55 channels of digital-to-analog and 48 channels of analog-to-digital communications. All of these facilities are available for data processing purposes.

OPTICAL SIGNAL PROCESSING FACILITY

This facility, now under construction, is being designed as a general purpose, coherent optical signal processing laboratory. Initially, the equipment will be used to process the data from our submarine infrared wake experiments. However, the equipment will be utilized in the future for processing data obtained from many other sources.

The facility will consist of a granite surface plate, a high power cw laser, an optical bench, and various optical and photographic equipment. The granite surface plate will measure 4 x 8 x 1-1/3 feet, and will be placed on top of dampened spring mounts supported by a steel stand. In addition to being a stable base for our optical equipment, the surface plate will be also an optical bed for hologram (wave front reconstruction) experiments. The laser will be a continuous wave He-Ne gas laser operating in the visible red spectrum (6328 Angstroms) with an output power greater than 50 mw. It will also be able to operate in the infrared region of the spectrum. The optical bench will be two meters long with movable mounts for holding the various lenses, mirrors, filters and other optical and photographic equipment needed for the optical signal processing.

TYPICAL PROGRAMS FOR LABORATORY

The laboratory is well equipped for the study of the following ASW research and simulated tactical problems:

1. Acoustic characteristics of underwater sound sources
2. Calibration and development of underwater instrumentation
3. Generation and study of echoes from submarine targets
4. Acoustic geometry problems involving straight line, multiple signal-paths; multiple signal-sources; multiple noise-sources, etc.
5. Propagation of electromagnetic radiation in conducting media (water)
6. Interaction of electromagnetic radiation with submarine generated phenomena
7. Simulation of ocean waves
8. Simulation of submarine wakes
9. Simulation of ocean hydrodynamics
10. Simulated radar detection of submarines
11. Simulated infrared detection of submarine wakes
12. Construction of optical and acoustic holograms
13. Optical signal processing
14. Analog and digital signal processing
15. Spectral characteristics of water samples.

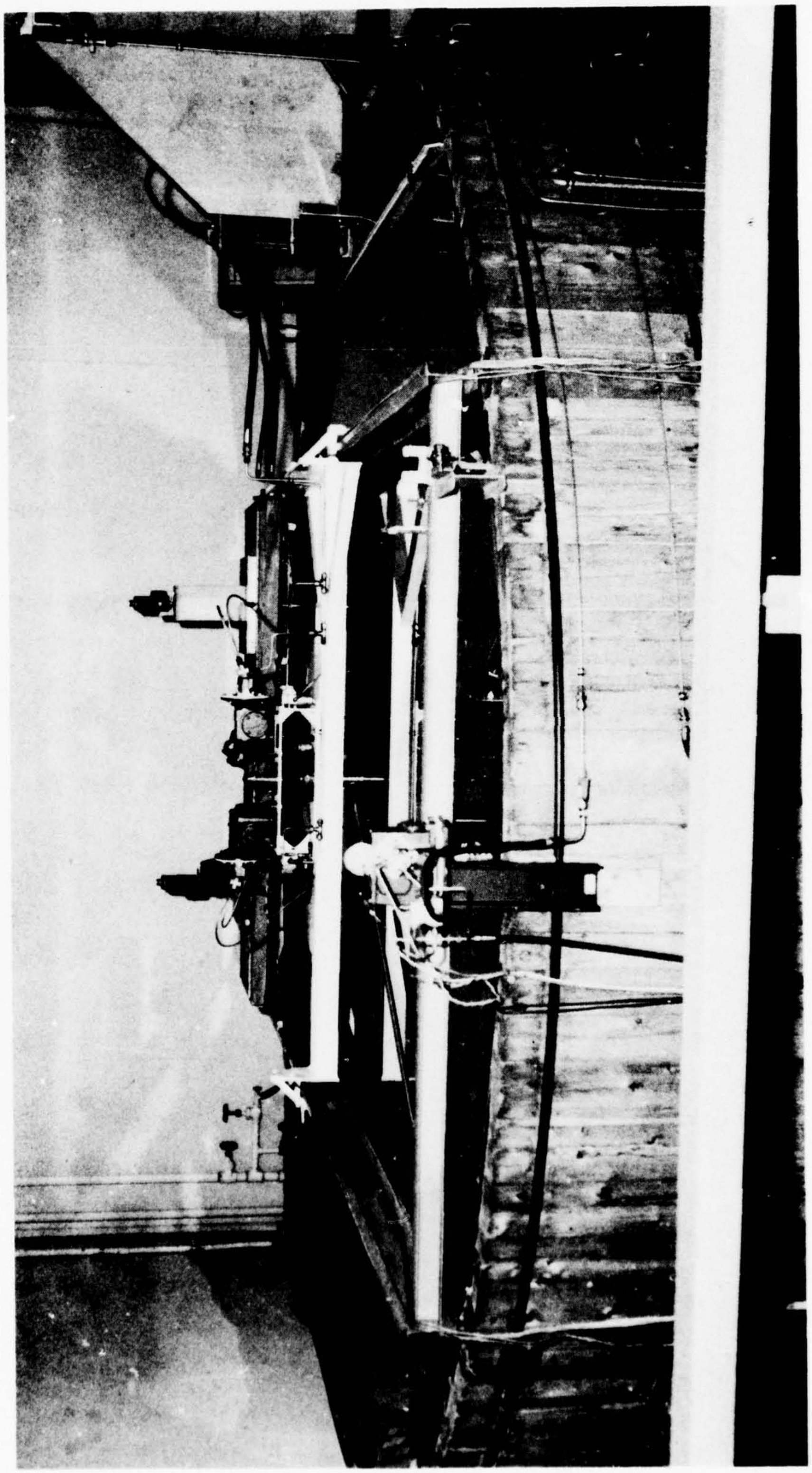


Fig. 1 Hydroacoustic Tank and Electro-
Mechanical Handling Equipment

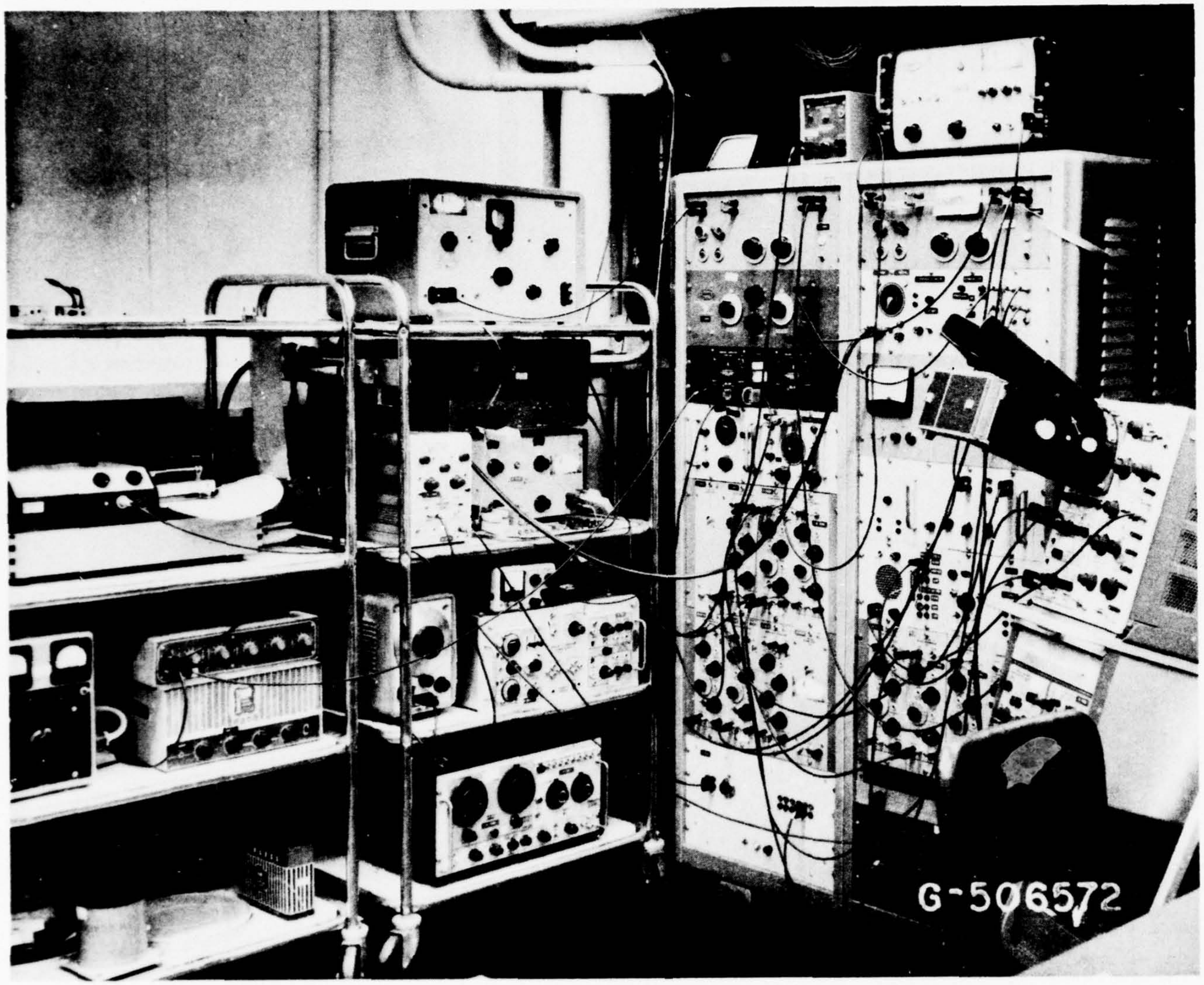
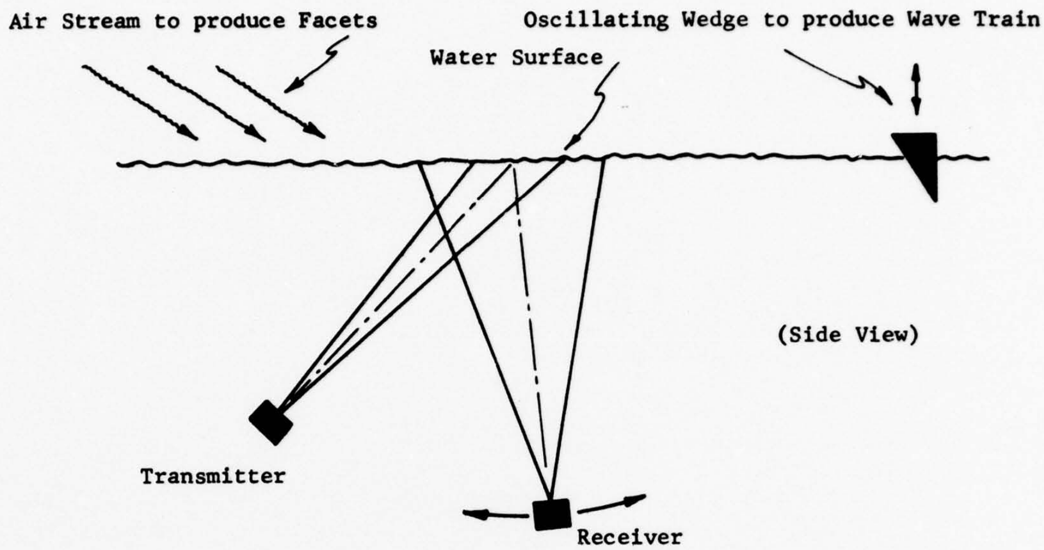


Fig. 2 Electronic Equipment in the Hydroacoustic Facility



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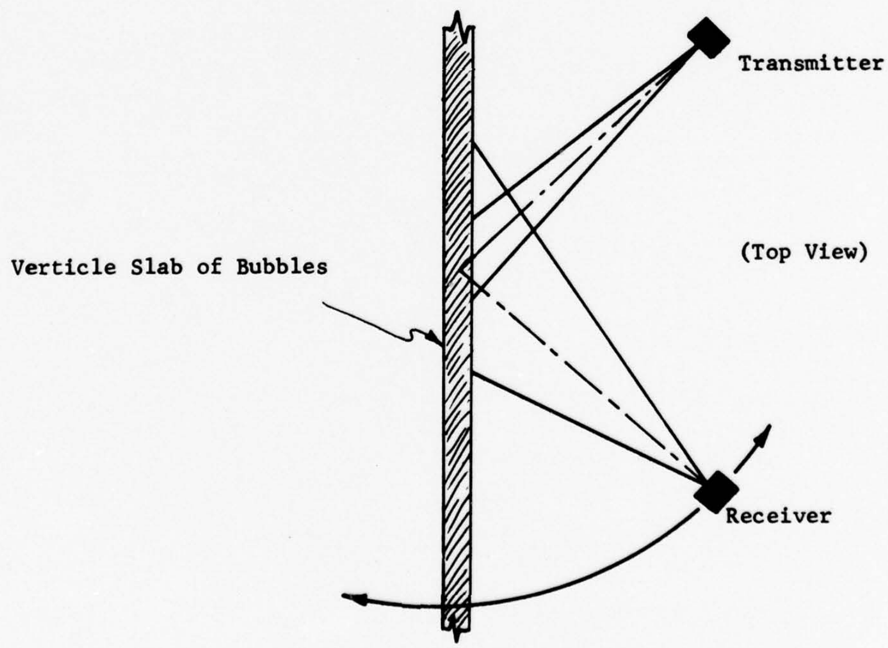

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Fig. 3 Schematic of Laboratory Data Collection Method Using Submerged Swings

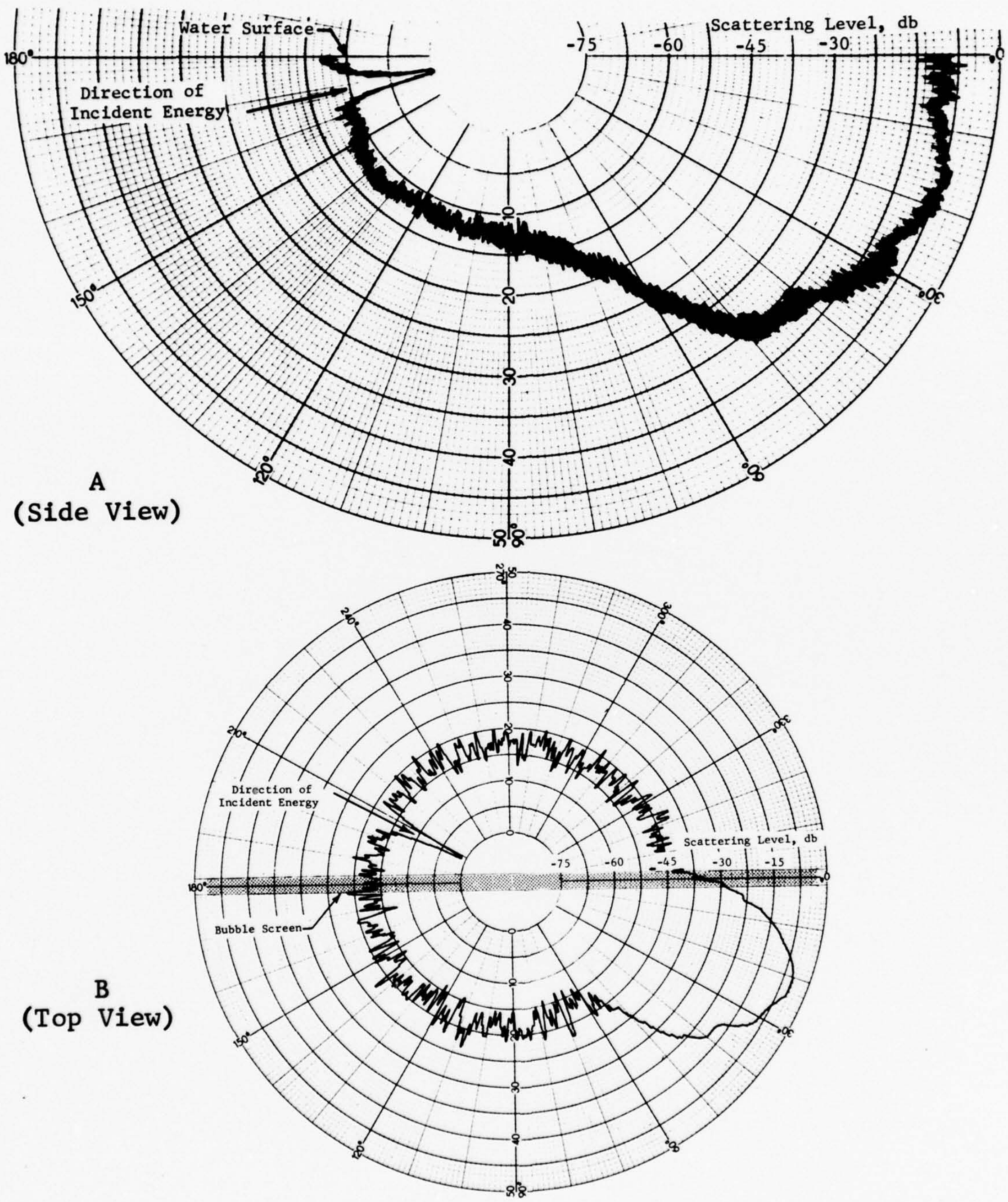


Fig. 4 Typical Polar Plots of Acoustic Scattering

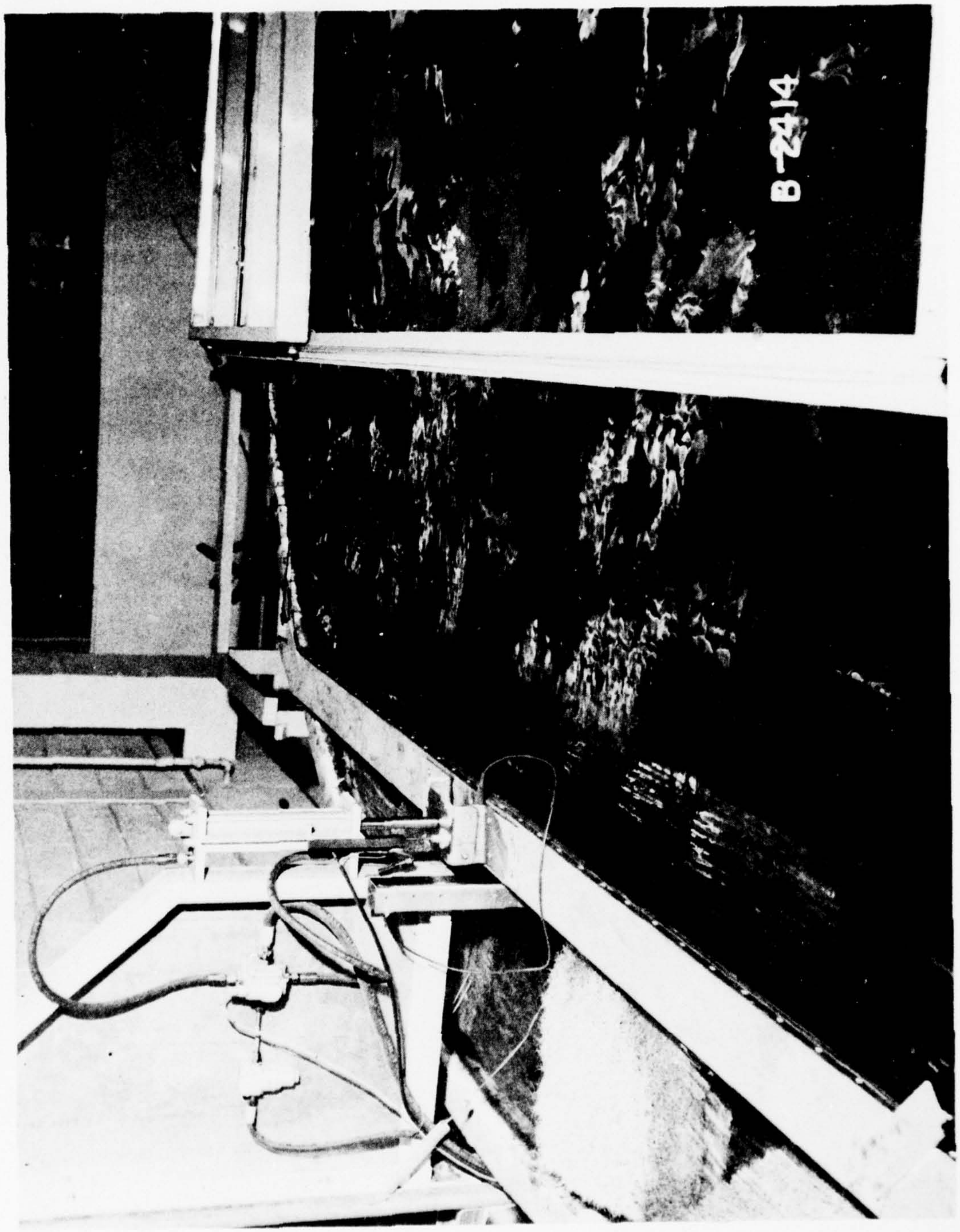


Fig. 5 Wave Generator

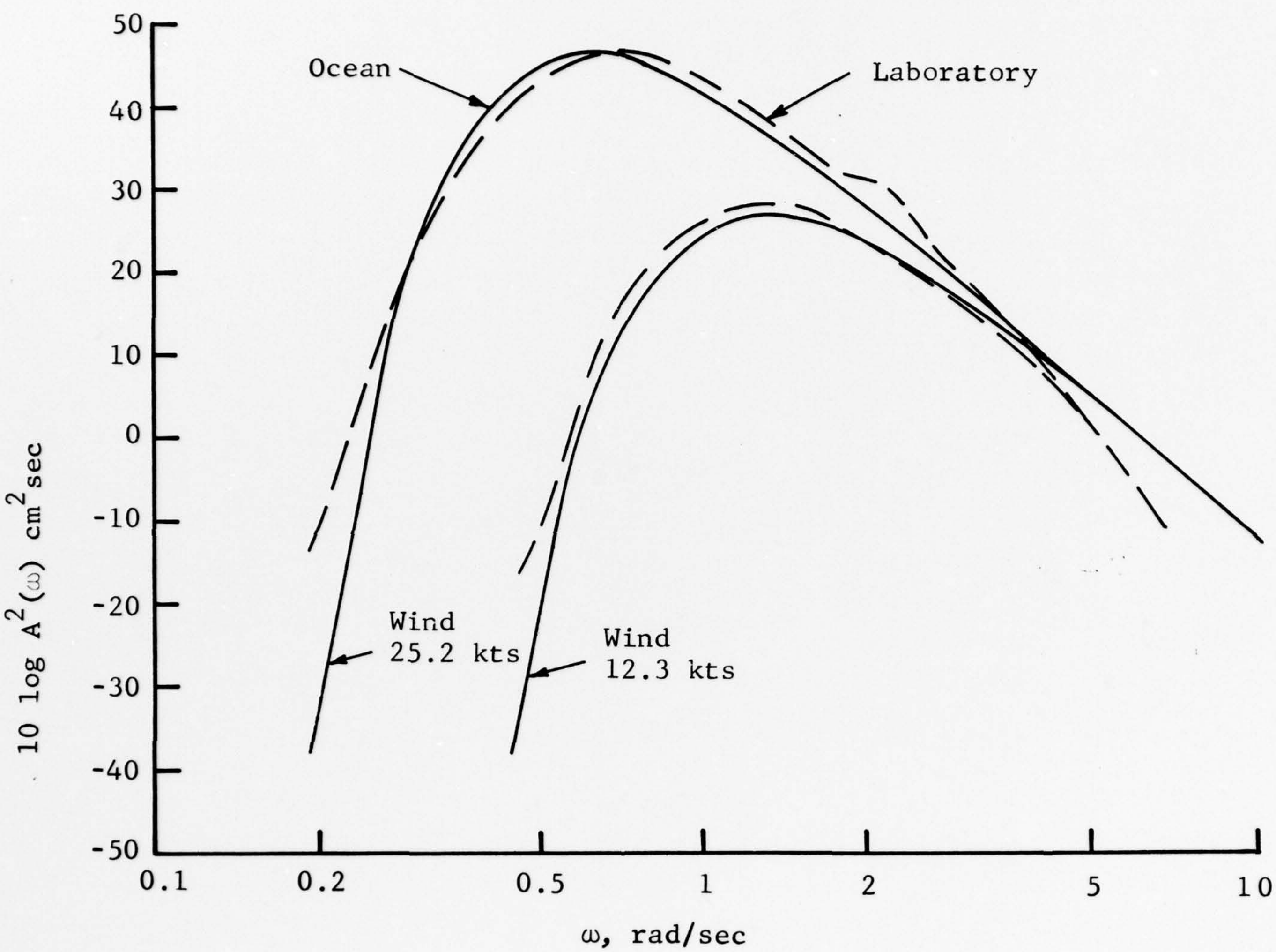
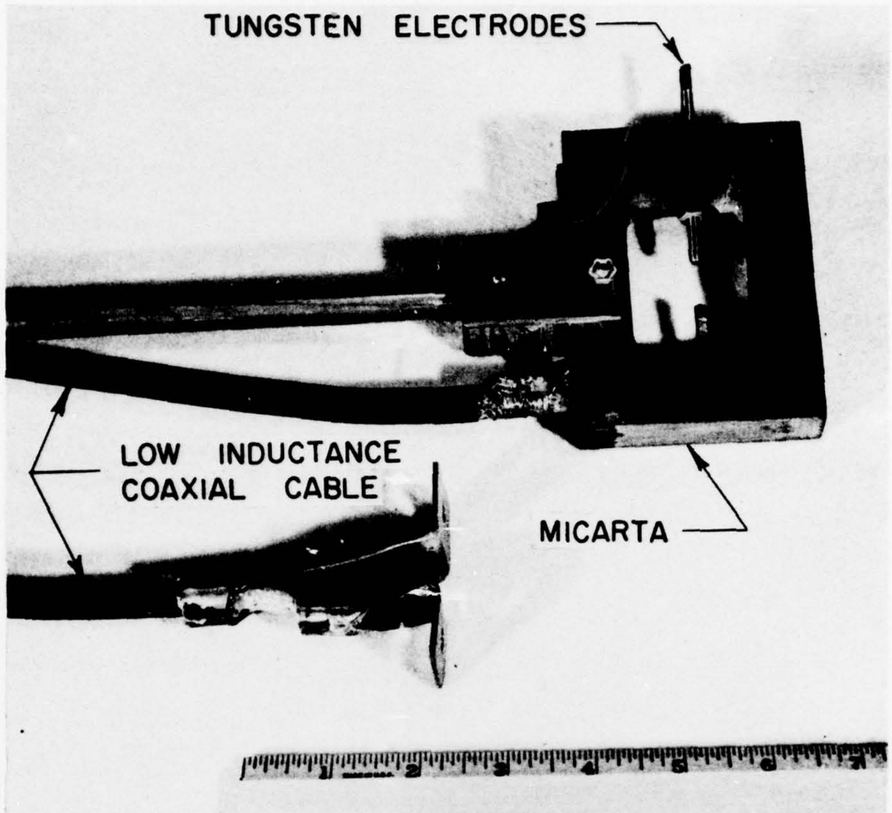
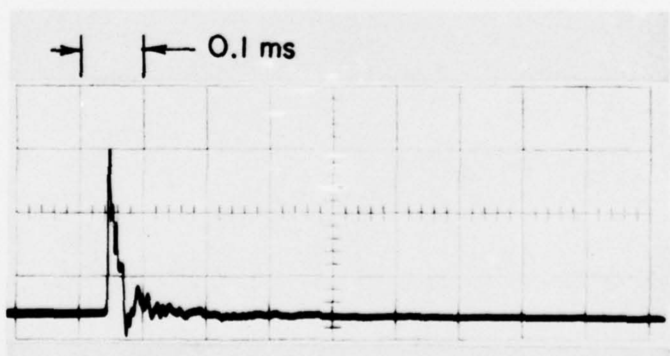


Fig. 6 Spectrum of Fully Developed Sea

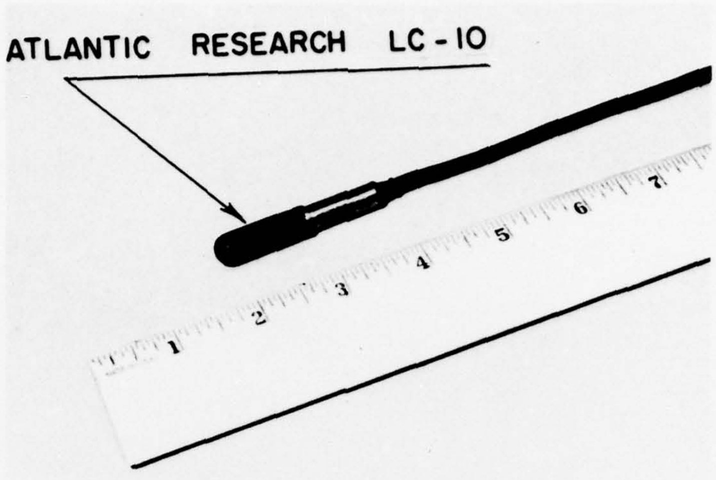


SPARK ELECTRODES AND HOLDER

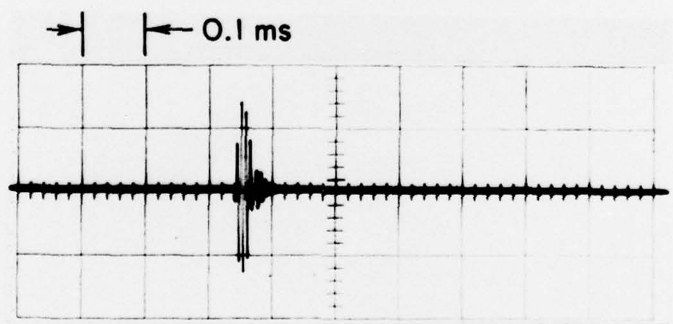


ACOUSTIC OUTPUT

Fig. 7 Underwater Spark Acoustic Source

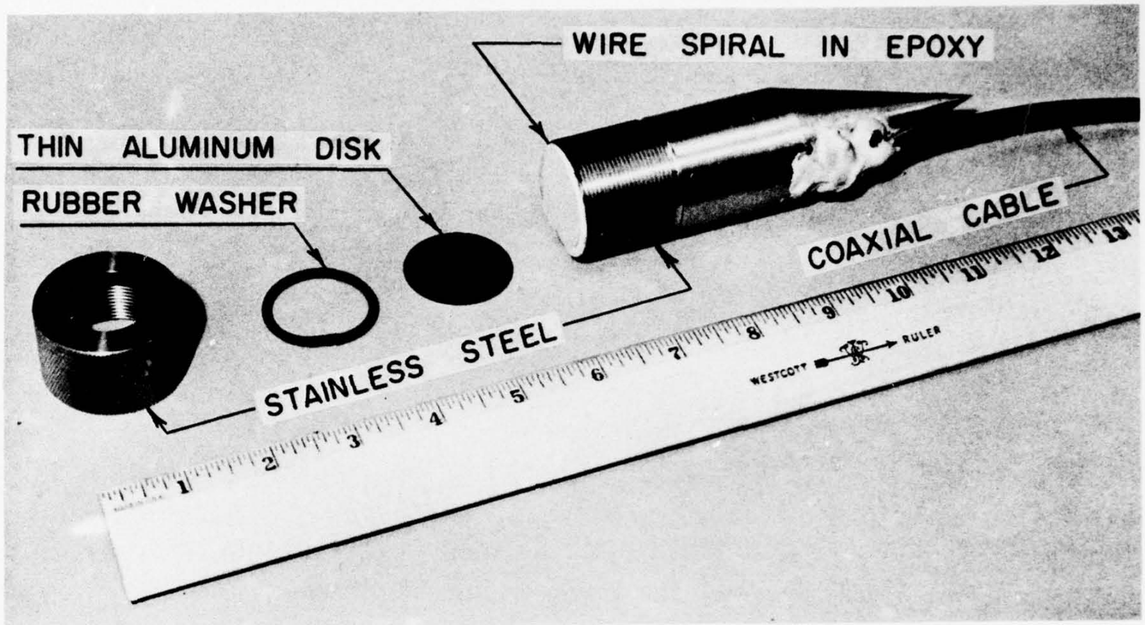


HYDROPHONE

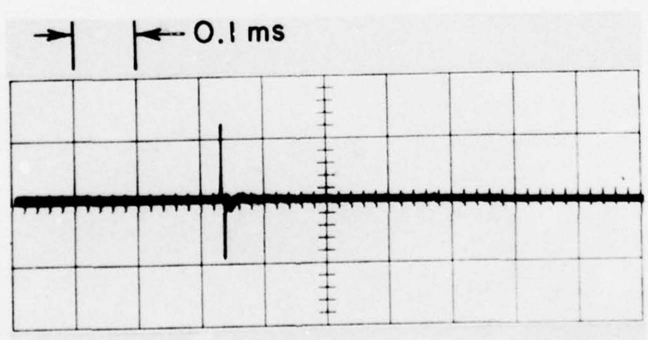


ACOUSTIC OUTPUT

Fig. 8 Hydrophone Acoustic Source



ACOUSTIC SOURCE



ACOUSTIC OUTPUT

Fig. 9 Eddy-Current Acoustic Source

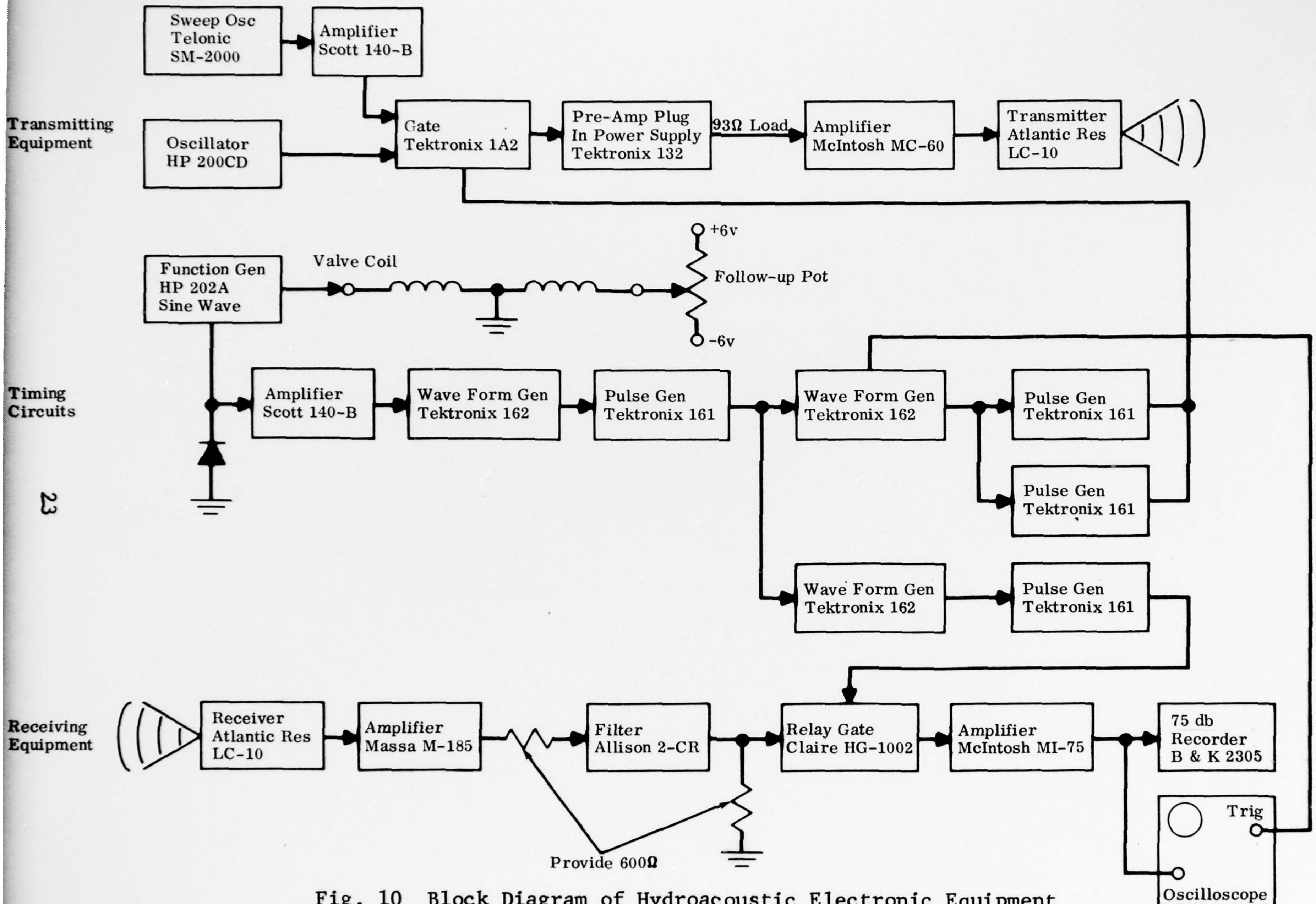


Fig. 10 Block Diagram of Hydroacoustic Electronic Equipment Used for Acoustic Reverberation Research

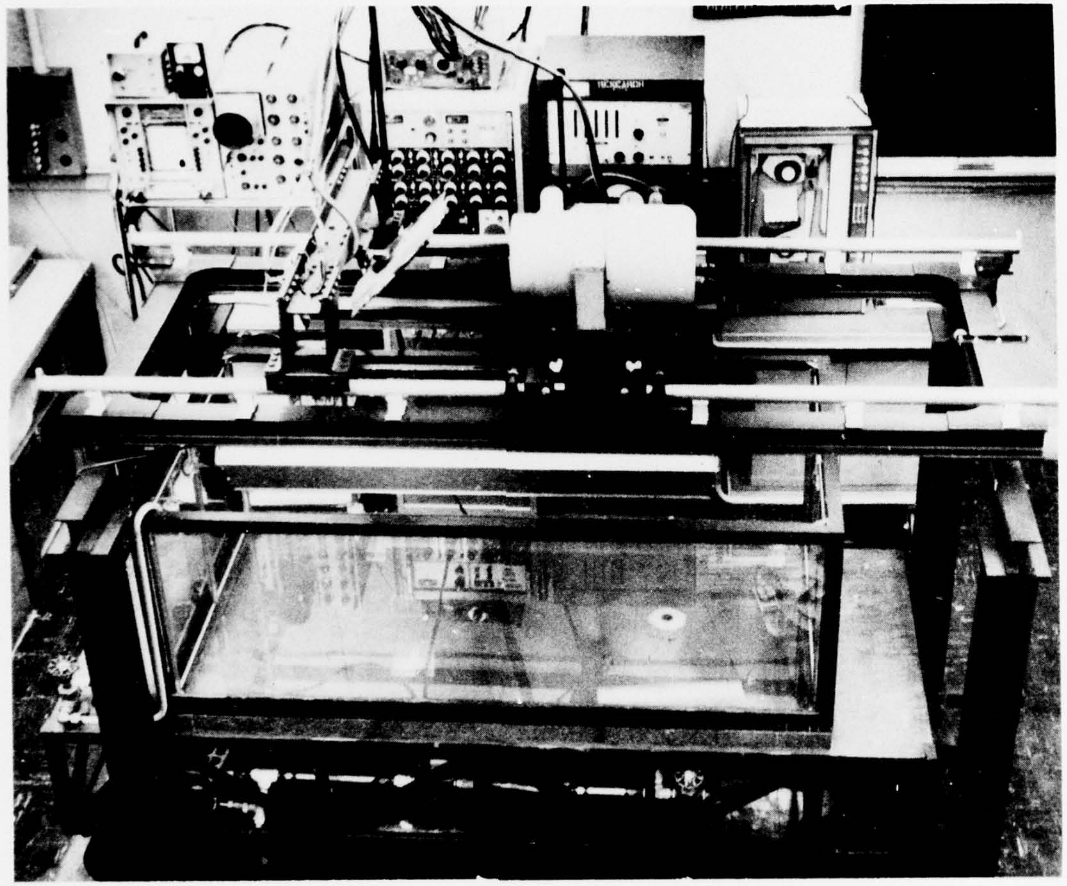


Fig. 11 Infrared Wake Detection Facility

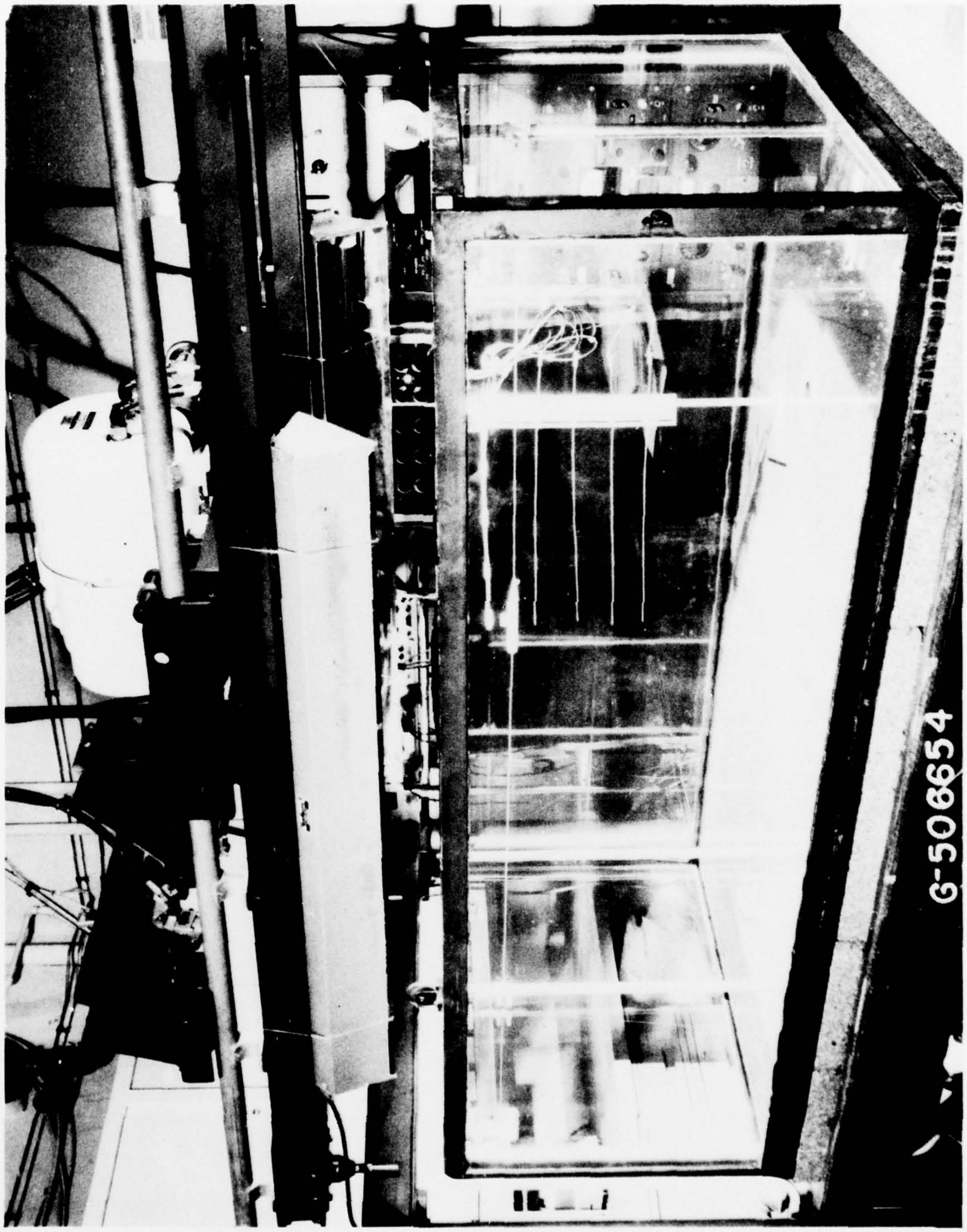


Fig. 12 Infrared Wake Dection Tank

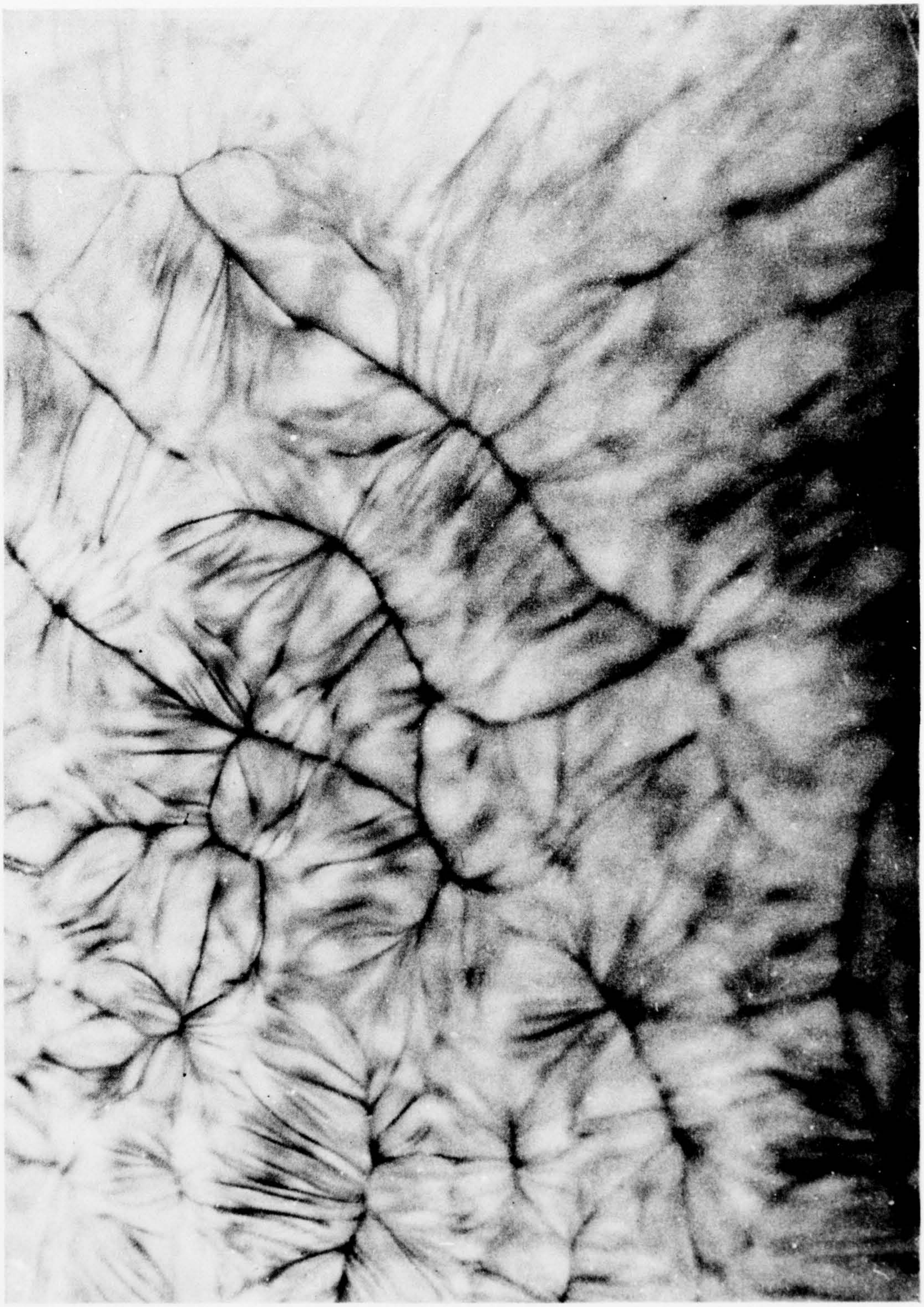


Fig. 13 Convective Circulation of Water

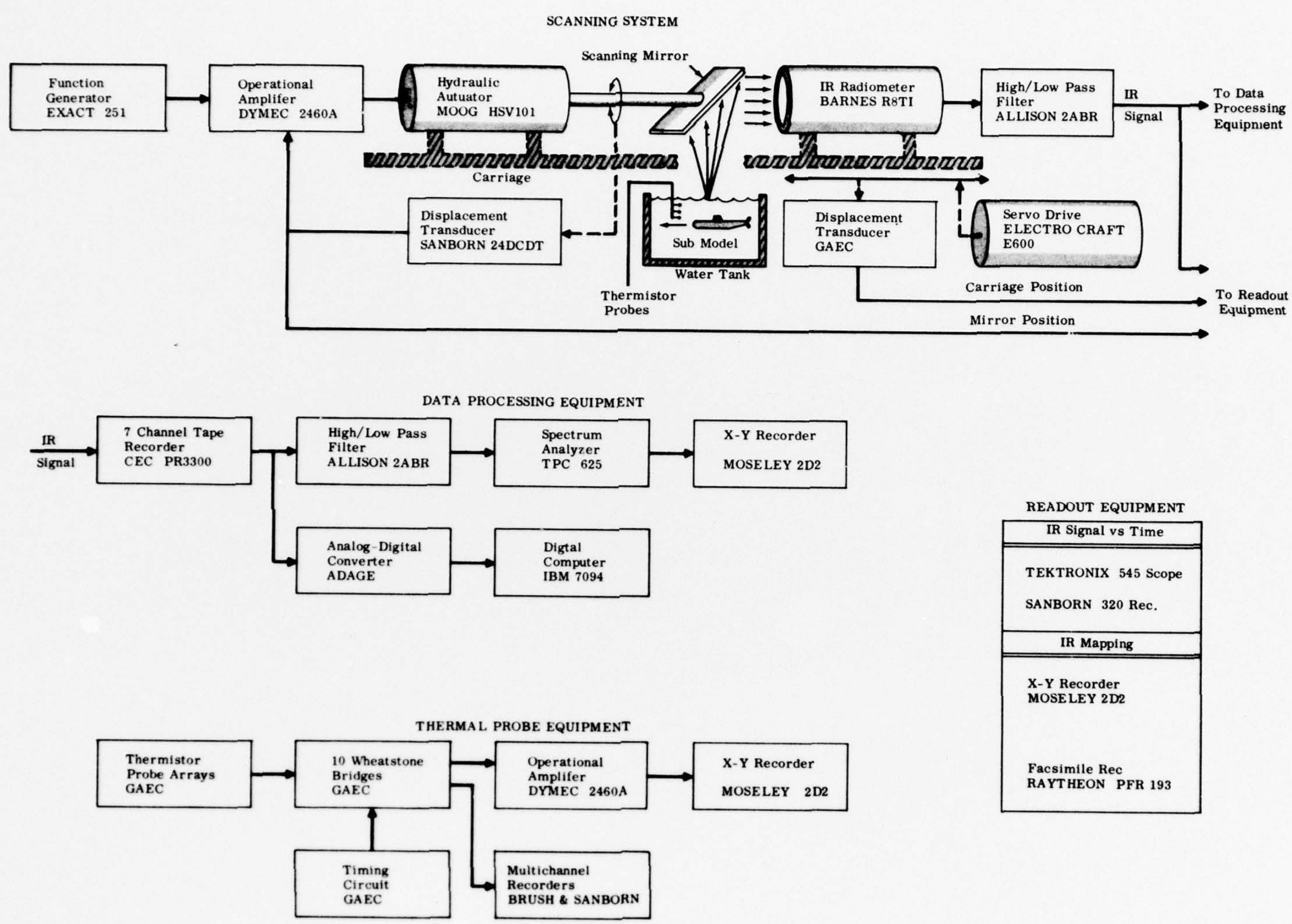


Fig. 14 Block Diagram of Infrared Electronic Equipment

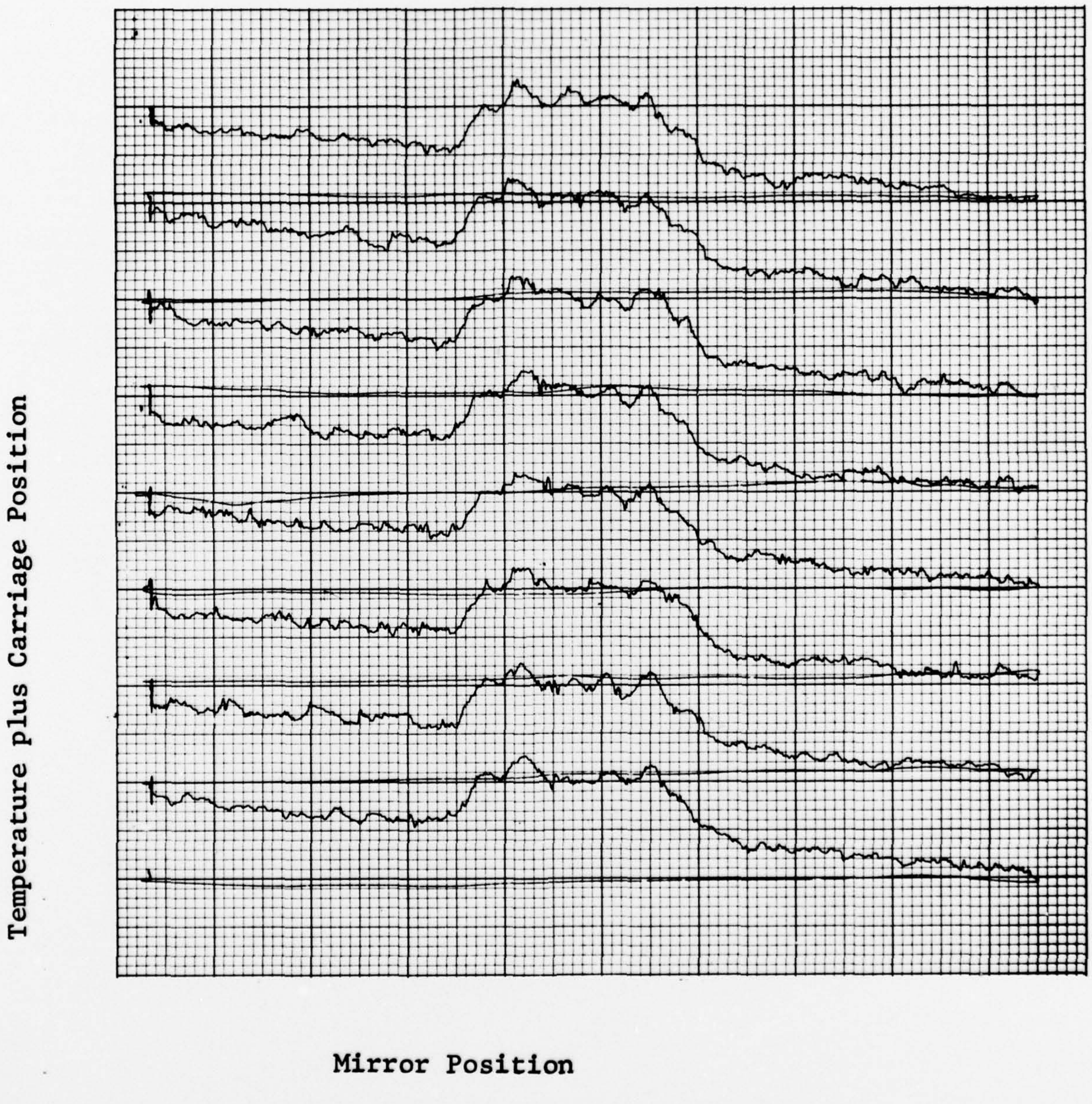


Fig. 15 Typical Radiometric Recording of Water Surface Temperature

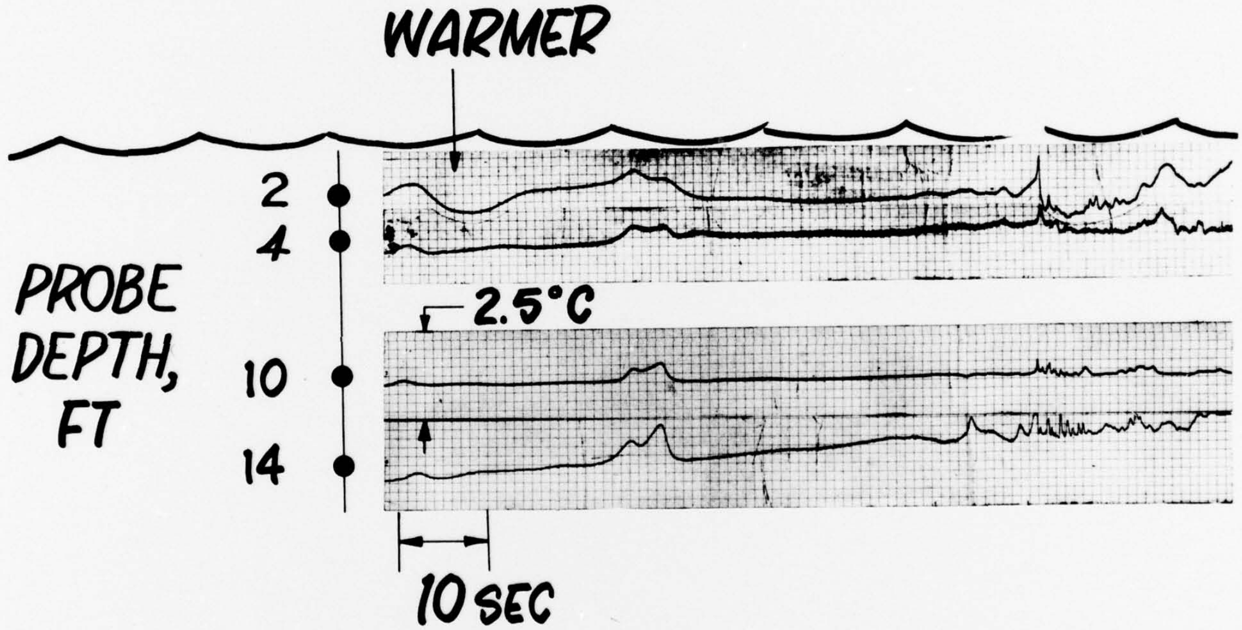


Fig. 16 Thermal Structure in the Water Recorded Continuously by Thermal Probes

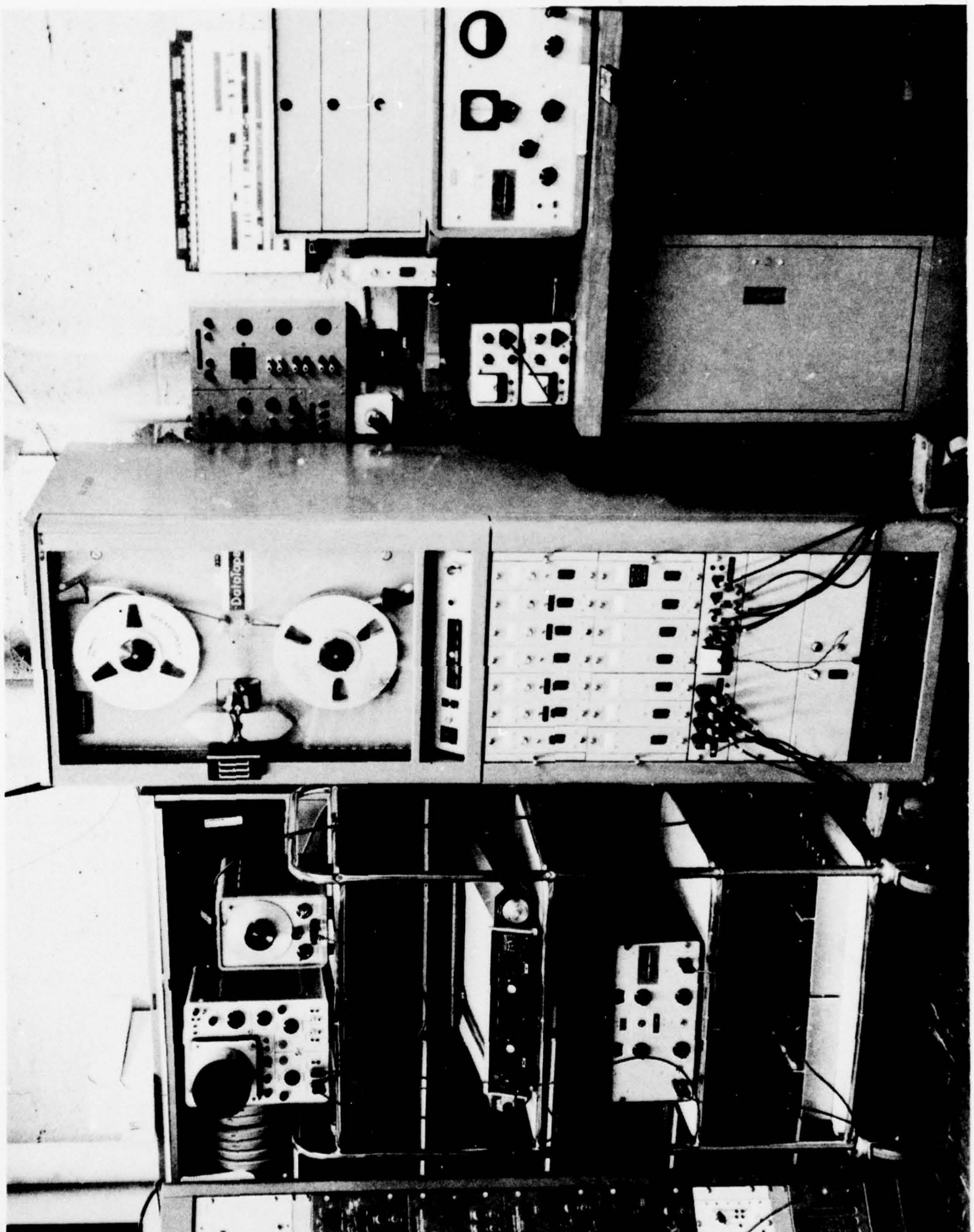


Fig. 17 Signal Analysis Facility

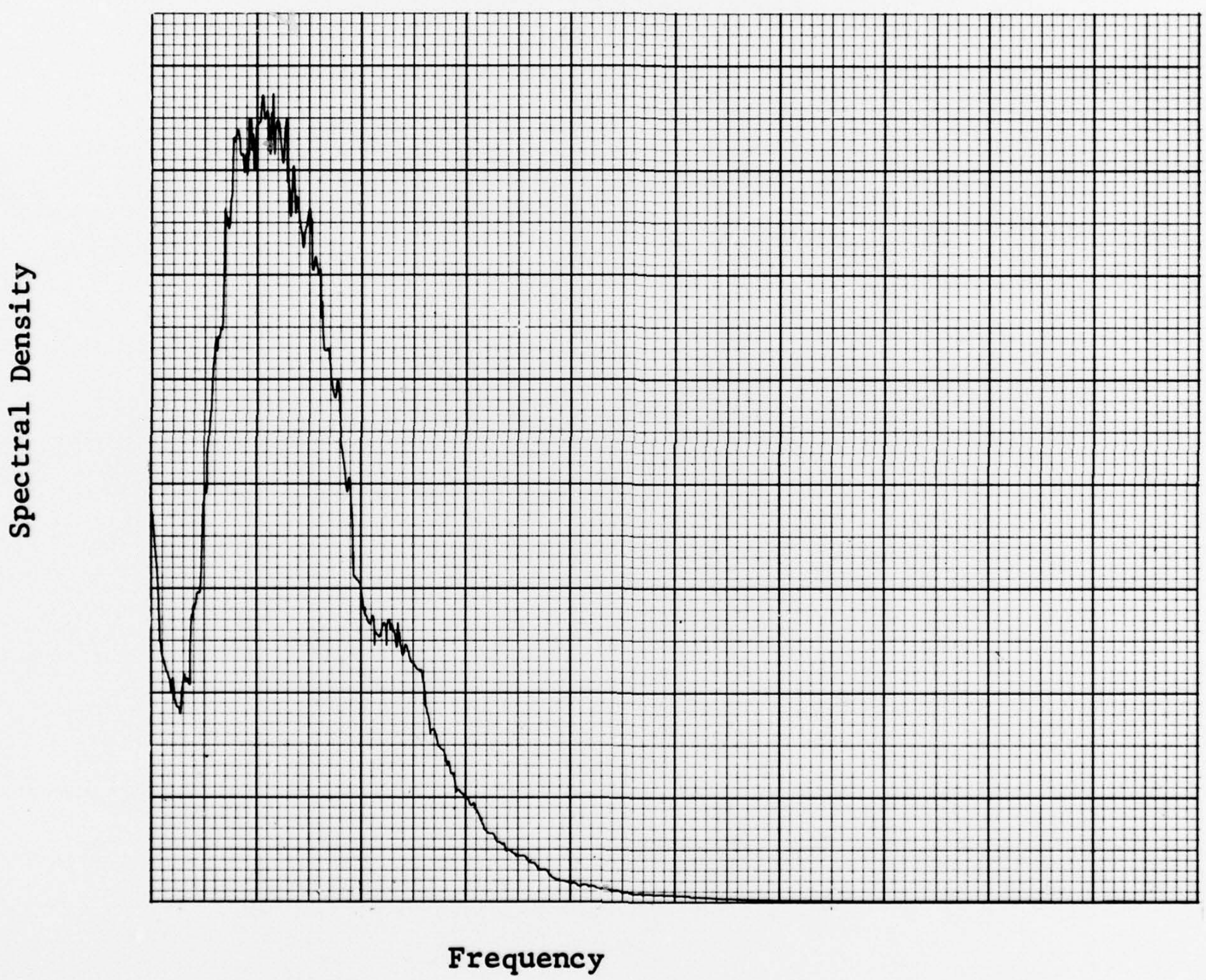


Fig. 18 Infrared Wake Power Spectrum Obtained by Analog Equipment

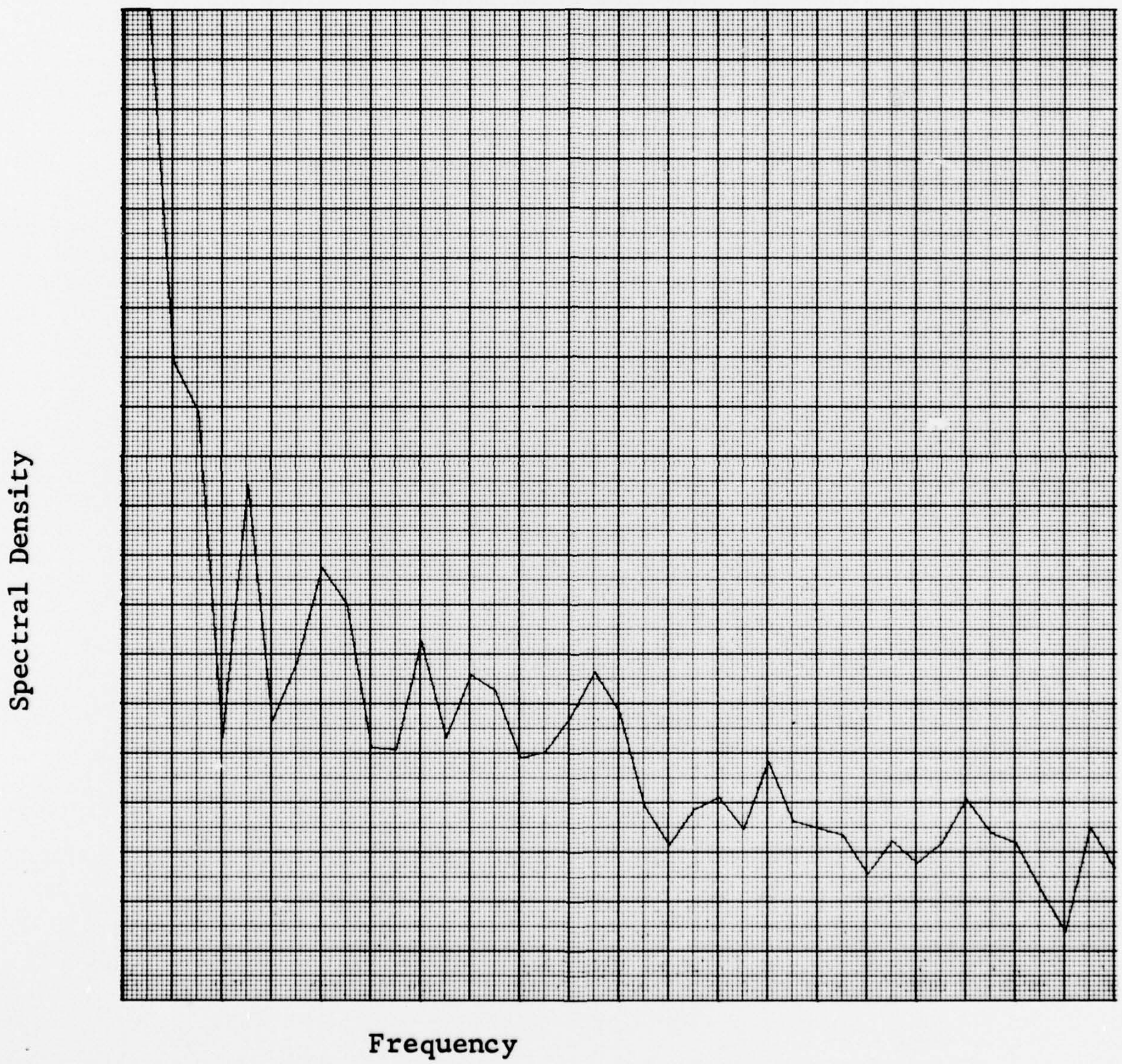


Fig. 19 Infrared Wake Power Spectrum Obtained by a Digital Computer